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EFFECTIVE E-WASTE MANAGEMENT: THE ROLE OF INTERNATIONAL COOPERATION AND FRAGMENTATION

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ABSTRACT
E-waste problems related to trade in wastes and informal recycling in the developing countries address environmental, social, and economic effects. Moreover, given on multiple aspect considerations, it is found that currently recycling fragmentation trade presents. This paper first reviews the driving forces of international trade in wastes and characters fragmentation in recycling industry. In the premise that environments and economic/social benefits can be exchanged among countries, we offer managerial conditions on international cooperation solution that increases e-waste treatment cooperation and fragmentation and contributes to effective e-waste management.
Keywords: e-waste management, recycling fragmentation trade, international cooperation importing countries, exporting countries, environment

INTRODUCTION

The primary issues related to e-waste problem (wastes of electrical and electronic equipments, WEEE) arise from not both quantities and hazardous and toxic materials. Additionally, recycling a huge amount of electronic disposals results in environmental injustice and transnational pollutions as considerable quantities of wastes are not recycled domestically but rather shipped to developing counties, in which inappropriate and informal recycling causes severe damages to environments and human health (BAN and SVTC, 2002; Widmer et al., 2005). Apart from economic aspect, current pollution effect on e-waste is global and not local which calls for cooperative endeavours on managing e-waste crisis. Thus, different policies and initiatives appear to be designed and implemented at both national and global levels, which are including: EPR policy, WEEE in Europe, RoHS in Europe, the Basel Convention, Basel Ban and StEP initiative. However, evidence shows that existing policies directions will mitigate but not solve problems of legal and/or illegal transboundary movement of wastes, informal recycling in industrializing countries, and a global perspective on e-waste management and sustainable development (BAN, 2007; Kahhat and Williams, 2009; Widmer et al., 2005; Williams et al., 2008).

The objective of current cooperative implementation endeavour at international level is to let parties reach their commitment to minimize waste generations and manage wastes within their borders. Unfortunately, the fact is that both developed and developing counties fails to fulfil the restrictions and enforce or implement proper environmental standards due to economic and social considerations. For exporting countries, recycling companies and traders intend to transfer environmental externalities based on cost difference consideration (Chen and Sheu, 2009). On the other hand, most importing countries allow waste trade because recycling is viewed as a business opportunity of providing cheaper secondary materials and employment for the poor communities. Even environmental concerns have spilled over into the trade; both exporting and receiving countries currently try to obtain positive effects of trade and put less attention on the externalities of trade (Chen et al., 2009). It is found that rationale and approaches behind existing cooperative mechanisms are not working effectively.

As we know, legal/illegal trade in wastes continue to this day. Interestingly, trends and patterns in waste trade have changed. In the past, most used EEE products are shipped from the developed countries to the developing countries. This is generally a port-to-port

trade in nature. Recently, given on multiple considerations, it is found that a treatment fragmentation phenomenon appears in recycling industry — cross-border dispersion of e-waste treatments, with each country specializing in a particular stage of the processing sequence based on its own regulations and specific needs (Athukorala and Yamashita, 2006; Yi, 2003). There is a clear example of Peru: the main purpose of imports of used PCs in Peru is basically reuse oriented. If these importing end-of-life equipments are identified not worth reselling or refurbishing, they will be dismantled into different parts and materials which are recycled domestically or exported to China and/or Europe (Kahhat and Williams, 2009). Such changing trends and patterns in waste trade are also among East Asia countries, particularly between Japan and China. The wastes of materials and components generated in Japan export to weaker economies for recovering recyclable resources, which provide local manufacturers in the receiving countries and Japan cheaper secondary materials (Zeng and Zeng, 2007).

International vertical specialization in manufacturing industries is well known, but waste fragmentation trade, reflected mainly in the trade in parts and materials of e-waste, is new form of trade in wastes and is less known than the conventional trade in final obsolete EEE products. Many questions arise within the presence of e-waste treatment specialization. What is the character of fragmentation trade of e-waste? Are recycling networks leading to any benefits and impacts for both importing countries and exporting countries? Is studying such new form of e-waste recycling system beneficial in providing more information about environmental and economic implications of different choices?

Based on the discussion above, the context we wish deal with is the following. Considering a situation that each of countries faces a waste trade constraint in the form of conditional utility trade-off between economic/social and environmental aspects, in which exporting/importing pollution-intensive products have an incentive to reach minimizing environmental effects and maximizing economic/social effects at the lowest possible cost. Our first aim is then to characterize the driving forces of international trade in wastes and the presence of recycling fragmentation trade, and check if cooperative solutions for waste trade may help resolve some or all of e-waste problems. Secondly, this paper explore that given what kind of cooperative conditions of driving forces, fragmentation trade in e-waste behave strategically to facilitate the solutions to problems.

In the next section, this paper will character the driving forces of international trade in wastes and the presence of e-waste fragmentation trade by drawing on insights from recent research on WEEE recycling and management. We also review relevance studies and outline benefits and effects of recycling fragmentation within both importing countries and exporting countries. The following is that we provide views on conditions in the context of embedding international cooperation solution in e-waste treatment fragmentation, which may contribute to effective e-waste management. The discussion and concluding remark are included.

REVIEW OF PAST STUDIES

In this section, we review of past studies from various categories: e-waste generation and flows, driving forces of international trade in wastes, and recycling fragmentation trade.

E-waste generation and flows

Rapid leap in information technology and innovation is expected to lead to e-waste generation at an alarming rate of obsolesce. It was estimated that 2 million tonnes of e-waste generated in the Unites States in 2000, and the overall e-waste volume was estimated at 5 to 7 million tonnes and are likely increasing by 3% to 5% per year. Due to lake of standard categories and definitions of e-waste and difference of take-back legislations among countries, the data and figures are not reliable but are projected to be higher today and rapidly increasing (BAN and SVTC, 2002; Terazono et al., 2006). Managing increasing quantities of used EEE appliances poses a challenge to policy

makers. Table 1 presents the estimated amount of e-waste and its categories in selected countries.

Country	E-waste generated (tonnes/year)	Categories of e-waste	Year
Switzerland	66042	Office & telecommunications equipments, consumer entertainment equipments, large and small domestic appliance, refrigerators, fractions	2003
Germany	1100000	Office & telecommunications equipments, consumer entertainment equipments, large and small domestic appliance, refrigerators, fractions	2005
UK	915000	Office & telecommunications equipments, consumer entertainment equipments, large and small domestic appliance, refrigerators, fractions	1998
Denmark	118000	Electronic and electrical appliances including refrigerators	1997
USA	2158490	Video products, audio products, computers and telecommunication equipments	2000
Canada	67000	Computer equipments, consumer electronics	2005
Taiwan	14036	Computers, home electrical appliances	2003
Thailand	60000	Refrigerators, air conditions, TVs, washing machines, computers	2003

Table 1 Estimated e-waste volume and categories in the selected countries.
Source: Terazono et al. (2006)

Figure 1 is used to indicate main e-waste flows in Asia; however, no reliable data and figures available on how these transboundary e-waste routes are because currently the illegal and unregulated sector dominates the recycling industry in the industrializing countries (Widmer et al., 2005). As such, there are many obstacles revealed in safely and effectively processing electronic disposals.

Figure 1 The routes of e-waste in Asia

Source: Widmer et al. (2005)

Driving forces of international trade in wastes

Drawing upon literature, there are three driving forces of cross-border movement of wastes identified as follows: legal and policy, economic value, and social consideration. The three categories above may have individual significant influence on current e-waste management and sometimes they may act as dynamic and interacted effects.

The first key factor is legislations and regulations which contribute to legal/illegal waste trade. According to research by Yoshida and Kojima (2008), inconsistency of environmental standard and waste definition among countries leads to free-rider problems and failures of controls on trade. From a legal standpoint, however, due to lack of relative legislations and/or lax of enforcement, it is possible for countries to manage end-of-life electronic goods cross their borders (Hicks et al., 2005; Widmer et al., 2005; Yang et al., 2008). For example, electronic disposal may be exported in the names of mixed metal scraps and other components if they can be used as raw materials; the exports of recyclable wastes and secondary goods which may contain hazardous substances and materials are recycled and cause pollutions in receiving countries at the end of products' usages (BAN and SVTC, 2002; Yoshida and Kojima, 2008). Moreover, in response to highly environmental awareness and highly stringent regulations, recyclers may in turn export wastes for easy solutions for waste treatment because of increasing treatment costs and facilities investments. Recycling plastics in Japan is a good example for illustrating how some countries use legal exemption to transfer the externalities of costs to weaker economies (Zeng and Zeng, 2007).

Economic value is also expected to contribute to trade in wastes. There are many examples as follows: (1) for recyclers in the exporting countries, due to higher recycling costs raised from higher labour and investments on treatments and facilities, the adoption of exporting wastes is an effective management to lead to the economic benefits of comparative advantage; (2) evidence shows that some obsolete but functional EEE equipments are viewed as "wastes" in developed countries, but they are sold as "new" products in developing countries after repairing and refurbishing. The highly monetary margin is driving to waste trade (Stricher-Porte and Yang, 2007); (3) depending on value of scraps, wastes may be recycled locally for valuables and remaining less- or non-valuable materials/components are exported to other countries for further processing and landfills (Terazono et al., 2006; 2007); and (4) the growing demand for recyclable resources is also an essential contributor to encourage growing trade in recyclable wastes (Hicks et al., 2005).

Thirdly, for many developing countries, imports of secondary electronics/e-wastes benefit in helping the poor, solving digital divide problem and providing cheaper EEE products, which reveals social benefits of trade in wastes (Widmer et al., 2005). Many importing countries view "recycling" as a business opportunity which provides huge employments for poor communities. Peru imports an increasing number of used computers from US over time and the major purpose of imports is oriented toward reuse as opposed to recycling (Kahhat and Williams, 2009). In the industrializing countries such as China and India, the majority of imports of used IT appliances can be sold as second-hand or new goods after repairing or refurbishing activities. The poor in the industrializing countries can own IT products at the lower costs than in the developed countries (Li et al., 2006; Yang et al., 2008).

Recycling fragmentation trade

The driving forces above may result in that the obsolete EEE products are traded among not only two single destinations but also multiple destinations. Moreover, some other variables such as technology and complexities of EEE equipments also influence the routes of end-of-life electronic goods, resulting in the phenomenon of recycling fragmentation trade, in which used EEE products are treated in multiple and sequential

stages and two or more countries provide value added in the waste's processing sequence. Figure 2 indicates the patterns of recycling fragmentation trade in different countries and each stage provides value added in the recycling sequence to gain revenues. In sum, regardless of what kind of considerations, inputs may need to cross multiple borders in order to gain environmental and/or finance profit benefits within a trade provision case.

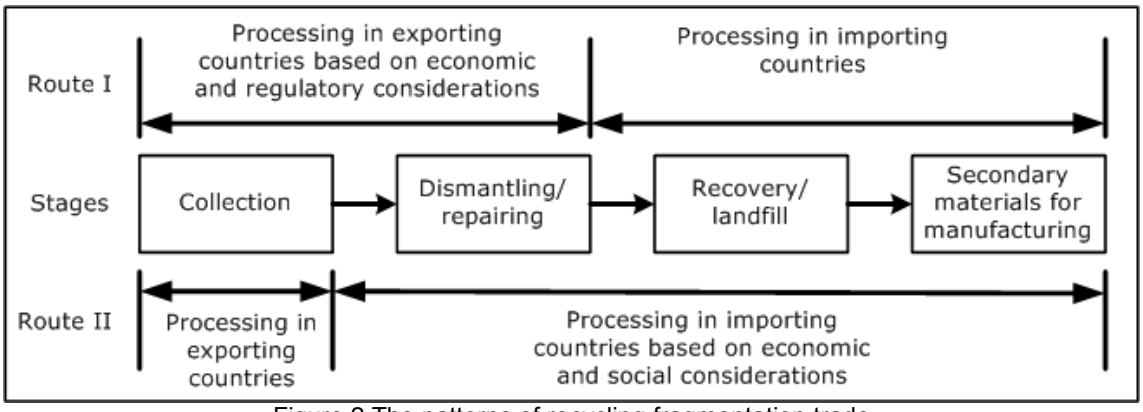

Figure 2 The patterns of recycling fragmentation trade

Because WEEE contains many hazardous and toxic substances and materials, which may cause serious air, water and soil pollution, as well as damage to human health if improperly handed. Therefore, while companies in recycling industry may reach global economic efficiency through fragmentation option, the environmental externalities have spilled over into the issues of trade in wastes. This paper is intended to neither discuss this controversial issue nor provide a conclusive suggestion for the best solution. In contrast, we aim to explore the presence of e-waste recycling fragmentation and provide views on the other possibilities of alternative practices on WEEE management. Table 2 presents the positive and negative effects on recycling fragmentation in both exporting and importing countries, which enables the multidimensionality of problems and policies to be taken into account and is beneficial in developing feasible and effective of implementation. After all, current research provides too little about environmental and economic implications of different choices (Williams, 2005).

	Exporting countries	**Importing countries**
Positive benefits	● Minimizing amounts of wastes recycled domestically ● Minimizing pollutions ● Increasing financial profits	● Providing cheaper secondary products, components and materials ● Generating job opportunities ● Solving digital divide ● Promoting recycling industrial scaling-up and technology advancement
Negative effects	● Causing environmental injustice when exporting hazardous and non-recyclable wastes ● Facing obstacles of changing regulations in importing countries	● Increasing environmental and human health risks
Negative effects for both countries	● Increasing illegal trade ● Increasing difficulties on monitoring and controlling trade ● Increasing illegal storage and dumping when hard to recycle at the possible cheaper costs	

Table 2 Positive and negative effects of recycling fragmentation trade

DISCUSSION AND PROPOSITIONS

We consider WEEE management with regulatory, environmental, economic, social and technology aspects, formulating our propositions in which given what kind of cooperative conditions of driving forces, recycling fragmentation trade behave strategically to facilitate the solutions to e-waste problems. Since environmental concerns have spilled over into the trade negotiation process, the terms of trade taxes, tariffs and subsidies in the economics analysis are incorporated into cooperative plans and implementations (Cassing and Kuhn, 2003; Copeland, 2000). Inspired by the literature on cooperation game and fragmentation (Athukorala and Yamashita, 2006; Lejano and Davos, 1999), three scenarios are considered and will be defined rigorously later on: (1) *single country scenario:* each country chooses its waste amount and recycling instruments so as to optimize its own welfares without facing an environmental constraint; (2) *multiple destinations in two single countries scenario:* each play's optimization is as in the previous scenario. In this setting, countries may incorporate restriction on environmental policy into trade agreements and seek equality associated with cost and/or benefit allocation based on the bilateral cooperative mechanism; and (3) *multiple countries scenario:* cooperative setting and framework among multiple countries is as in the previous scenario but each stakeholder can however make collective decision on fairness rather than decide on a personally optimization.

As mentioned, inconsistency of environmental standard and waste and second-hand product definitions among countries dramatically leads to free-rider problems and failures of controls on trade. If the fairness of distribution of costs and benefits is possibly achieved by the cooperative mechanism among countries, countries may have greater willingness to make a collective decision on bilateral and/or multilateral contracts and agreements. As a result, the likelihood of traceability of the traffic and data of wastes will be increased; government agencies can easily control the illegal movement of wastes and guarantee that wastes are recycled with safely and efficient treatment. As such, we present proposition 1 as follows,

Proposition 1: The higher consistency of environmental standards and regulations among countries is decreasing in the illegal trade, increasing in the recycling fragmentation in scenarios 2 and 3, and increasing environmental and profitable strategic purposes on e-waste management.

From economic perspective, we focus on the value of wastes and secondary materials. China becomes the key recyclable resources importer in the world because of growing demand for cheaper secondary materials. The financial profit has strong incentive for dealers to trade wastes without considering environmental externalities and trade barriers, resulting in illegal trade and severe damages to human and environment. If equitable and effective trade agreements subject to cooperation by special interests of each player are developed, this arrangement can force exporting countries internalize environmental effects through tariffs or subsidies while importing countries gain economic and social benefits. We therefore provide proposition 2,

Proposition 2: The greater difference of value of wastes and recyclable resources is increasing in the movement of wastes, increasing in recycling fragmentation scenarios 2 and 3, and increasing in environmental and profitable strategic purposes on e-waste management.

In the case of Peru, multiple purposes of imports of wastes lead to fragment recycling activities into several stages in different countries. Imports of used computers in Peru are mainly used for secondary goods and end up with metal recovery purpose. Furthermore, after the dismantling process recyclers in Peru may process computer parts and materials domestically (e.g., copper cables) or export them to China and Europe (e.g., circuit

boards). If arrangements are developed based on optimizing each party's welfare, components and materials may ship to country which provides environmental friendly treatment. As such, recycling fragmentation trade is helping solving e-wastes problems associated with social benefits and pollutions. Such a condition leads to proposition 3.

Proposition 3: The more purposes of wastes and second-hand goods is increasing in the movement of wastes, increasing in recycling fragmentation scenarios 2 and 3, and increasing in social and environmental strategic purposes on e-waste management.

The key driver to fragment recycling activities across borders can be waste treatment technology. As electronic and electrical wastes are diverse and complex, in terms of the type, size, and shape of materials and components, recycling processes and facilities play a critical role in developing a cost-effective and environmental friendly recycling system (Cui and Forssberg, 2003). Besides, when arranging trade-off of benefits and externalities of specialization, increased flows of capital and technology among countries complement recycling sharing, allow firms to extend recycling networks and promote recycling industrial scaling-up in importing countries. Proposition 4 is provided as follows,

Proposition 4: The greater difference of recycling technology is increasing in the movement of wastes, increasing in recycling fragmentation scenarios 1, 2 and 3, and increasing in environmental and profitable strategic purposes on e-waste management.

CONCLUSION

This paper first reviews the driving forces of international trade in wastes and characters fragmentation in recycling industry. In the premise that environments and economic/social benefits can be exchanged among countries, we offer managerial conditions on international cooperation solution that increases e-waste treatment cooperation and fragmentation and contributes to effective e-waste management.

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